UNPUBLISHED PRELIMINARY DATA

THE ANTENNA LABORATORY

RESEARCH ACTIVITIES in ---

108

Automatic Controls — *Antennas* — *Echo Area Studies*
Microwave Circuits — *Astronautics* — *E M Field Theory*
Terrain Investigations — *Radomes* — *Systems Analysis*
Wave Propagation — *Submillimeter Applications*

SEMI-ANNUAL REPORT
1 November 1962 to 30 April 1963

Grant No. NsG-213-61

1388-10 — 1 June 1963

Prepared for: National Aeronautics and
Space Administration
Washington 25, D.C.

Department of ELECTRICAL ENGINEERING

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION
Columbus, Ohio

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REPORT

by

THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION
COLUMBUS 12, OHIO

Sponsor	National Aeronautics and Space Administration 1520 H Street, N.W. Washington 25, D.C.
Grant No.	NsG-213-61
Investigation of	Theoretical and Experimental Analysis of the Electromagnetic Scattering and Radiative Properties of Terrain, with Emphasis on Lunar-Like Surfaces
Subject of Report	Semi-Annual Report 1 November 1962 to 30 April 1963
Submitted by	Antenna Laboratory Department of Electrical Engineering
Date	1 June 1963

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SEMI ANNUAL REPORT

A. INTRODUCTION

During the past year and a half, the Antenna Laboratory, under two National Aeronautics and Space Administration grants, has been engaged in a fundamental study of the relations between the scattering processes of moon-like surfaces and their surface structure. The significance of such a study for lunar and planetary research has been outlined in previous proposals and progress reports.[1, 2] More recently, the introduction of more sophisticated techniques in lunar mapping radars (e.g., high resolution doppler mapping, and frequency modulation methods of short-pulse synthesis[7]) have re-emphasized the need for basic data on surface scattering, in order to interpret such experiments. Indeed, the use of the term "ambiguity diagram" to describe the performance of these new radars against even the simplest point targets gives a strong indication of difficulty in learning about surface structure from the analysis of scattered signals. The problem may be still further complicated in the near future if a suggested experiment were to be carried out[6] to make bistatic measurements of the lunar scattering using the approach radar of the next "Ranger" series.

B. PROGRAM REVIEW

To provide the fundamental data needed to interpret or design planetary radar experiments, we have been engaged in a number of theoretical and experimental studies which are briefly reviewed below. More detailed information may be found in progress reports of the project.[1, 2]

1. Back-scattering Measurements from Moon-like Surfaces

A large number of measurements of the back-scattering from a variety of rubble like surfaces have been carried out for a wide range of incidence angles and polarization states. These measurements have provided a basis for the interpretation of the diffuse component of the lunar scattering[3, 4] in terms of a surface roughness, and a surface dielectric constant.

During the last few months a facility for making bistatic scattering measurements of rubble-like surfaces has been completed, and a measurement program has begun.

2. Theoretical Studies

Theoretical studies have been aimed at an interpretation of the lunar scattering diagram, and have included: analysis of the specular part of the lunar scattering in terms of a physical optics model,[4] which predicted a non-gaussian second probability distribution and gave an estimate of the rms slope of the intermediate scale features of the lunar surface; fundamental studies in radar photometry, including the solution of the doppler mapping problem in closed form;[5] studies of the polarization transforming properties of rough surfaces, with application to the interpretation of lunar radar experiments using linear polarization.

3. Lunar Radar Experiment

Preliminary studies have been made of a proposed CW lunar radar experiment to be performed using The Ohio State University "Saucer Field" receiving system.

It was originally planned to use The Ohio State University "Saucer Field" array as a receiver, and take advantage of several transmitters operated by other organizations for lunar illuminations. However, this has not been a satisfactory approach so we recently acquired a 10 KW transmitter, and an antenna mount. We are now installing this system at Ohio University in Athens, Ohio in order to give us a complete radar system, thus permitting control of frequency, polarization modulation, etc. We expect this radar to be in operation during the last few weeks of the grant. In the meantime system design studies have been carried out, particularly with respect to doppler mapping with a CW transmitter.[5]

C. PROPOSED WORK PROGRAM FOR THE REMAINDER OF THE PRESENT CONTRACT

For the remainder of the present contract period, it is expected that our major effort will be directed towards measuring a number of rubble and other rough surfaces, using the bistatic measurement facility. Particular attention will be given to obtaining data for several polarizations, and over a wide range of surface-roughness to wavelength ratios. It is expected that this data will be of importance not only for the interpretation of bistatic radar experiments, but also in estimating the emissivity of the moon, and thus in interpreting the many measurements of the apparent temperature of the lunar surface.

It is also hoped to measure some artifically constructed surfaces (including some cusped and some tuff-like surfaces) to check physical optics and semi-empirical scattering laws (e.g., the Lommel-Seeliger law) at bistatic angles.

In addition to this major measurement program, the program of theoretical studies will be continued. In the next six month period, attention will be concentrated on further system studies of the doppler mapping technique, particularly with reference to the experiment with The Ohio State University "Saucer Field" array. The consequences of the coherence properties of the surface on system design, and on the interpretation of the experimental data, will be studied. These system studies will be carried out parallel to the development of the radar facility itself. However, because the progress of the instrumentation program at the receiver array is not directly controlled under this grant, it is difficult to predict a precise time table for this aspect of our proposed work.

D. PROPOSAL FOR COMING YEAR (November 1963-October 1964)

For the next year, in order to continue the program of studies on the radiating properties of moon-like surfaces, the following course of work is proposed.

1. Bistatic Surface Measurements

Although the bistatic radar facility is now complete, it is not expected that sufficient data can be taken with it by the end of the present contract. Thus it is planned to continue the measurements with this facility. As experience is gained, it may be desirable to make some changes to obtain a wider range of aspect angles (this is particularly likely for angles near grazing) or a further number of polarization states.

Among the experiments that would be of interest are a detailed comparison between theory and experiment on surfaces that correspond to theoretical models, particularly models that should lead to the "classical" scattering laws (Lommel-Seeliger, etc.), which have often been used but never verified in the microwave region. Attention will also be given to polarization transformations, the relation between the "optical" scattering level and the surface dielectric constant for rough surfaces, and the relation between surface scattering and thermal emissivity.

2. Theoretical Studies

Theoretical studies should be continued in two directions. In the first place, the interpretation of the bistatic measurements described above will require analysis of the scattering from the particular surfaces used. The large amount of data that can be gathered under such a program can not be fully exploited unless it is organized or reduced, and the parameters (roughness, dielectric constant, etc.), which control the scattering are identified.

For this reason, it is proposed to undertake a study of the characteristics of non-uniform surfaces which can affect the scattering process, with the aim of providing some useful taxonomic system which can associate scattering behavior with some quantitative description of the surface.

In the other direction, it is hoped to continue the general study of radar photometry, with special attention directed to the analysis of the more sophisticated radars now coming into use. In particular, the effects of extended rough surfaces with given coherence properties on the radar ambiguity diagram should be worked out, and the implications for radar mapping determined.

3. Lunar Radar Experiment

The measurement of the scattering properties of the moon using doppler techniques, with The Ohio State University Saucer Field and 10 KW transmitter, should be continued. This would permit a check of the pure doppler method against the known pulse methods for determining planetary scattering diagrams. At the same time, theoretical studies aimed at more complex, quasi-CW techniques should be continued.

4. If certain suggested[6] bistatic measurements of the lunar scattering are carried out (using the Ranger approach radar and ground based receivers of the Lincoln Laboratory or Jet Propulsion Laboratory) or if direct backscattering data should be telemetered from any of the Ranger series it is suggested that some effort from the above items (1, 2, 3) be made available for analysis of the Ranger data.

REFERENCES

1. "Semi-Annual Engineering Report," Report 1388-5, 1 July 1962, Antenna Laboratory, The Ohio State University Research Foundation; prepared under Grant No. NsG-213-61 for National Aeronautics and Space Administration, 1520 H Street, N.W., Washington 25, D.C.

2. "Annual Summary Report," Report 1388-7, 1 November 1962, Antenna Laboratory, The Ohio State University Research Foundation; prepared under Grant No. NsG-213-61 for National Aeronautics and Space Administration, 1520 H Street, N.W., Washington 25, D.C.

3. Peake, W.H. and Taylor, R.C., "Radar Backscattering Measurements from 'Moonlike' Surfaces," Report 1388-9, 1 May 1963, Antenna Laboratory, The Ohio State University Research Foundation; prepared under Grant No. NsG-213-61 for National Aeronautics and Space Administration, 1520 H Street, N.W., Washington 25, D.C.

4. Peake, W.H. and Ott, R.H., "Interpretation of the Lunar Scattering Diagram," Paper delivered at Fall 1962 U.R.S.I. meeting, Ottawa, Canada.

5. Compton, R.T., "The Solution of an Integral Equation for the Lunar Scattering Function," Report 1388-8, 1 April 1963, Antenna Laboratory, The Ohio State University Research Foundation; preparedunder Grant No. NsG-213-61 for National Aeronautics and Space Administration, 1520 H Street, N.W., Washington 25, D.C.

6. Private communication from Walter E. Brown, Jr. (Jet Propulsion Laboratory) to W.H. Peake.

7. Mehuron, W., "Lunar Measurement with a High Resolution Radar," Spring 1963, U.R.S.I. meeting, Washington, D.C.

In addition to Reference 4, the following paper, based on earlier work on the grant, was given.

8. Peake, W.H., "The Apparent Temperature of Isolated Objects," paper delivered at Spring 1963 U.R.S.I. Meeting, Washington, D.C.

THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION

PROJECT SUMMARY STATEMENT

SPONSOR National Aeronautics & Space Administration Washington 25, D. C.

DATE May 31, 1963

SUPERVISOR C. A. Levis

CONTRACT NO.

PROJECT NUMBER 1388

COST CLASSIFICATION	CURRENT MONTH		CURRENT BUDGET PERIOD 11/1/62 TO 10/31/63			
	BUDGET	EXPENDITURES	BUDGET	EXPENDITURES TO DATE	OUTSTANDING COMMITMENTS	UNENCUMBERED BALANCE
SALARIES AND WAGES		2,923.00	63,134.00	21,706.42	.00	41,427.58
MATERIALS, EQUIPMENT & SERVICES		436.09	10,966.00	3,396.11	1,325.55	6,244.34
TRAVEL EXPENSE		164.74	900.00	171.88	.00	728.12
OTHER DIRECT CHARGES						
OVERHEAD OR OPERATING CHARGES		1,139.97	20,000.00	8,352.58	.00	11,647.42
Equipment		50.47	5,000.00	1,113.20	.00	3,886.80
TOTALS CURRENT BUDGET		4,714.27	100,000.00	34,740.19	1,325.55	63,934.26
TOTALS OF PRIOR BUDGET PERIOD 11/1/61 TO 10/31/62		.00	50,000.00	48,339.31	.00	1,660.69
CONTRACT TOTALS		4,714.27	150,000.00	83,079.50	1,325.55	65,594.95

FORM 100

IMPORTANT NOTE: No deduction has been made from the Unencumbered Balance for future overhead charges.